Teaching programming through paperless assignments: an empirical evaluation of instructor feedback

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Title: Teaching Programming through Paperless Assignments: an empirical evaluation of instructor feedback

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Teaching Programming through Paperless Assignments: an empirical evaluation of instructor feedback

Abstract

This paper considers how facilities afforded by electronic assignment handling can contribute to the quality of Internet-based teaching of programming. It reports a study comparing the nature, form, and quality of feedback provided by instructors on 90 paper and electronic assignments in an introductory CS course and notes effective strategies for electronic marking.

Introduction: the importance of instructor feedback

Presentation of CS courses on the Internet is a boom business, promising the potential to attract students from around the globe. But what is the impact of Internet presentation on *teaching*? Is it possible to replace the individual feedback afforded in face-to-face teaching with electronic alternatives at global scale and still maintain quality? This paper compares quality of teaching in conventional and electronic media for one crucial aspect of interaction: feedback on student work.

Practical assignments are a major evaluation component in CS courses. Providing clear feedback (e.g., corrections to notation, alternative code, comments on structure) transforms an assessment mechanism into a teaching tool. The less chance there is to participate in discussion of course material, the more important specific feedback on student work becomes. For students studying independently at a distance, assignments are valuable opportunities for specific interactions with the teacher. Distance teaching 'culture' emphasises encouragement [1], and instructors usually provide more detailed feedback. Electronic assignment handling affords added potential for demonstration and execution, which have particular value in teaching programming skills.

This paper reports on a study giving attention to the nature, form, and quality of feedback provided by instructors on an introductory CS course who have both conventional and Internet students. Through analysis of comments on assignments, supplemented by questionnaires completed by both instructors and students, and by de-briefing meetings with instructors, the study addresses the following questions:

- Are the nature and quality of feedback comparable on paper and electronic assignments?
- Does the medium affect the students' or instructors' ability to express themselves adequately?
- How do marking an electronic document on screen or marking a paper document using a pen compare in terms of speed and difficulty?

The context, marking system, evaluation protocol, and analysis are presented in the following sections.

The context

This paper presents an analysis of material from a well-established, large-scale, distance-taught, traditional CS1 course using Pascal to teach the fundamentals of design and programming to some 2,800 students.

The university has well-established procedures for grading paper assignments which must be interpreted for electronic assignments. The lynch pin is a standard multi-part form which accompanies assignments and accumulates details from student, instructor, administrators and monitor in turn. Students submit assignments to their instructor, who notes grades and comments both on the cover form and on the assignment itself. The assignment is marked in conformance to a scheme specified by the Examination and Assessment Board which also sets the assignments and provides 'post-mortem' discussions of them. The instructor then sends the assignment to a central Assignment Handling Office which enters all the information into a database, verifies details, and returns the assignment to the student. If any of the details is incorrect, the instructor is contacted for corrections; this happens in about 5% of assignments (half a million assignments a year).

The electronic marking system

A complete system for electronic assignment handling has been developed. Students send their assignments electronically to a central automatic handler which verifies details, sends a numbered receipt, logs a copy of the assignment, and sends a copy to the instructor with a special data file. The instructor uses Microsoft Word 6/7 with a template developed for the course to mark the assignment, automatically converting the student document from its original format to the native format. The template uses the data file to complete an electronic version of the multi-part form with all of the details except the grades and the instructor's comments.

The template has a number of built-in tools to aid marking. The instructor can delete or insert text in any font or format anywhere in the document; inserted text appears underlined in blue, and deleted text is displayed with a red strike-through. Check marks and crosses can be inserted with a keystroke. Annotations can be added which provide a kind of hypertext comment (which appears in a separate frame on screen or as endnotes if the document is printed). Marks for questions are entered using a dialog box which automatically verifies that the grade is in the correct range for that question, copies the number onto the cover form, and adds up the marks. The drawing tools included in the word processor are available, so that freehand drawings are possible, although instructors were not briefed on this feature.

The instructor returns the marked assignment to another automated handler which records the grades in the university system, sends the instructor a receipt, and e-mails the assignment back to the student. Since the form filling and addition tasks are performed automatically, administrative errors of the type cited above do not occur. Students have been provided with a viewer application to browse and navigate through the returned document or print hardcopy. It should be noted that, although the marking tool is multi-platform, most students and instructors have low-specification PCs.

Design

The aim of this study was to give thorough scrutiny to a substantial corpus of assignments, giving particular attention to the comparison of electronic and paper treatments by each instructor. A secondary aim was to begin to unpick how individual instructor differences affect adaptation to electronic marking in terms of their strategies, their tool use, and the feedback they provide.

Students

The conventional course has over 2600 European students, with 95% from the UK; 80% are male and 20% are female. The Internet group has over 230 European students with 92% from the UK; 78% are male and 22% are female. Our questionnaire data does not indicate any significant differences in the makeup of the groups, and so we have taken them to be comparable except for the method of presentation.

Instructors

All instructors for the Internet groups are experienced, well-regarded instructors of the course in its conventional form. From these, three instructors, each of whom had students in each group, were selected on the basis of how many students they teach and how many assignments were available.

Assignments

This study examines 2 out of 8 assignments: the earliest substantive piece of work (48 examples) and the latest assignment available at the time of analysis (42). We examined 90 assignments: 46 paper and 44 electronic. The early assignment required presentation of program designs and short code fragments. The later assignment required more detailed designs, longer programs, program output, and short answer questions.

Coding protocol

The coding system, devised for capturing the quantity and nature of the feedback provided by each instructor, involved counting the occurrences of:

- general praise (e.g. “Good work”),
- specific or reiterative praise (e.g., “Your design here is concise and well-presented”),
- general corrections (what’s wrong; what’s important; e.g., “Take care over indentation”),
- specific corrections,
- substitutions of code,
- references to other material such as previous work, post-mortems, and course material, and
- questions to the student (e.g. “What would have happened if...?”)

We noted:

- re-use of previous material;
- occurrences of all non-text marks, including checks, crosses, strikeouts, circling, underlining, arrows, etc.;
- whether feedback was legible;
- whether the scope of comments was evident; and
- whether comments were clear.

We also examined the content and usage of the commenting.

Instructor feedback profiles

Each of the instructors (coded TA, TB, and TC) had a distinct feedback style, even though all three awarded grades consistent both for their own students and with each other, through both assignments and in both media. The monitor (a senior member of staff who reviews performance as part of quality assurance) confirmed that the quality, content, and quantity of comments were indistinguishable in the two media. Summaries of the instructors’ feedback styles are given in Table 1.

Summary Instructor Feedback profiles

	Instructor		
	TA	TB	TC
typing	fluent, 2-finger, 40wpm	fast, 10-finger	fluent, 50 wpm
marking strategy	by assignment, amassing reusable commentary	by assignment	by question
runs programs?	no	no	yes, selctively
feedback volume	high	high	low
general/reiterative praise volume	high	regular	regular, low
amasses corpus of comments	yes	no	yes
re-use of comments	yes, strategic	yes, seldom	yes, frequent
non-text mark usage	circles, arrows	many ticks, Xs, circles, arrows, etc.	few
hypertext comments	few	many	none

Table 1

The content of comments was comparable among the three. More comments were made on weaker scripts, concentrating on important and recurrent errors, noting significant ommissions, and including some praise. Fewer—but longer—comments were made on stronger scripts, including more detailed remarks on errors, picking out particular strengths, and asking questions that went beyond the assignment material. All gave attention to the student’s intention, execution, conformance to instructions, and style. All offered alternative code as well as annotations to students’ code; this applied equally to the instructors who re-used comments and the instructor wbo didn’t.

Quantitative Results

We used the ratio of the total number of comments of all types to the number of percentage points lost as a gross metric (*volumeRatio*). This showed a significant correlation for each instructor on each assignment (with one exception), as well as for each instructor on both assignments, and for all three instructors overall.

TA was the exception for the early assignment only. We had observed TA to give many comments, especially praise and other social comments, regardless of the number of points lost. Therefore, we computed a new value for the volume of comments which excluded all praise and ‘other’ (social) comments. This resulted in a significant correlation for TA as well as increased correlations for all of the other instructors, both on a per-assignment basis and overall. The correlation for all instructors was significant regardless of the medium (paper or electronic); these instructors are providing feedback in proportion to the points lost on both paper and electronic assignments.

Observations

Increasing familiarity with tool

TA, TB, and TC all showed more coherent marking strategies (i.e., matching facilities provided to the feedback being given) and more stable use of the features of the electronic marking tool (e.g., less chaotic use of the hypertext comments) by the later assignment, even though each used it quite differently. Additional features such as non-text marks, were used in the later marking.

Use of emphasis

Emphasis (underlining, circling, highlighting) is used less in electronic marking. This can be accounted for in part by the fact that instructors were not trained on how to use the drawing or highlighting tools available, and in part by the advantages gained from being able to embed comments directly in the student's work, so that the scope of a correction is indicated by adjacency. However, it appears that use of highlighting and circling will increase as the instructors gain experience with the tool.

Code corrections

Code corrections on paper were usually accomplished with circles, arrows, strike-throughs and inserted characters, or with chunks of substitute code written in the margin. Code corrections on electronic assignments were actually performed by the instructor, so that the result was correct code in line, yet the color and underlining showed which was the student's work and which was the instructor's. Clean handling of notation is an advantage of electronic marking of programs.

Legibility

In paper assignments, legibility is hampered mainly by the constraints of available white space, the quality of individual handwriting, and the permanence of the required ink. For example, TB often filled all available white space with (multi-directional) comments, and circles and arrows indicating where comments related to students' work. At high density, legibility was impaired, despite the instructor's efforts.

Mature electronic marking seems to have the advantage, assuming that the student has appropriate hardware:

- Legibility of individual handwriting is not an issue (whereas on paper, instructors report "writing rather slowly" to ensure legibility).
- Student work can be expanded, so that comments and corrections can be inserted in place as well as in the margins.
- Corrections to code are often clearer in electronic versions because students can see both their own work and the correct program.
- Transcription errors for replacement code chunks are avoided when cut-and-paste is used.
- Hypertext comments allow summary comments and assignment of points to be differentiated from specific corrections.
- Erroneous corrections can be un-done. Wording of comments can be revised.
- 'Pretty presentation' in uniform fonts and with regular indentation eases reading for both students and instructors.

Speed of marking

Speed of marking is largely dependent on typing speed: hunt & peck typers mark more slowly by keyboard than by pen, while experienced word processor users find that electronic marking saves time. Marking strategy also has an impact on speed. The current marking tool is slow in handling multiple files, and so strategies (like TC's) that involve swapping among different students' assignments carry higher overheads. On the other hand, electronic marking facilitates re-use of comments, and so strategies (like TA's) that plan for re-use benefit under this system.

Re-use

Re-use is evidently affected more by attitude than by medium. Whereas TA developed a strategy for amassing a corpus of high-quality re-usable commentary from which selections were made appropriate to individual work ("So I might take 3 or 4 times longer to work out what to say about a particular point but then I use it maybe six times and there's the payoff."), TB declared: "Each student has the right to an individual response!".

Viewing

None of these instructors reported printing out assignments. All remarked on the difficulties of viewing assignments on screen, largely due to individuals' equipment limitations; comparing files or pages was difficult on small screens, and slow scrolling accrues a noticeable overhead.

Administrative error

The error rate on the automatically-generated administrative forms for electronic assignments was 0%, while the error rate on paper assignments was in the neighbourhood of 5%.

Executable assignments

Although TC was the only instructor of the three to report running student programs ("I have run one or two programs and found they didn't produce the supposed results!") others remarked on the possibility. Students, too, can run substitute code, or substitute test input, provided by tutors. Handling assignments electronically lends a 'relevance' to the activity for CS students.

Turnaround time

Paper assignments mailed by the instructor usually arrive at the university the next day and reach the student after processing in another 5 days. Electronic assignments are e-mailed directly to the students after the instructor submits them to the university. Instructors report that turnaround for electronic assignments is usually 2-3 days, whereas turnaround for paper assignments is usually 5-7 days. Students report that the turnaround time for electronic assignments is 5-7 days, whereas turnaround for paper assignments is usually 2 weeks.

Summary

Within this sample, the nature and quality of feedback are comparable on paper and electronic assignments. Electronic marking does not impair expression. Many instructors report that the quality of their commenting is improved, indeed some report that they have been complimented by their students. Legibility is an advantage; as one instructor remarked: "Electronic assignment handling makes everyone's handwriting better."

Administration is faster and more efficient with electronic assignments. Students are pleased: turnaround time is reduced. Administrators are pleased: turnaround is efficient, less paper is consumed, and automatic logging increases accountability.

As instructors become more facile with the electronic marking tool and take up possibilities like non-text annotation, re-use, and running student programs, the particular advantages of electronic marking for programming assignments will become even more apparent.

References

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